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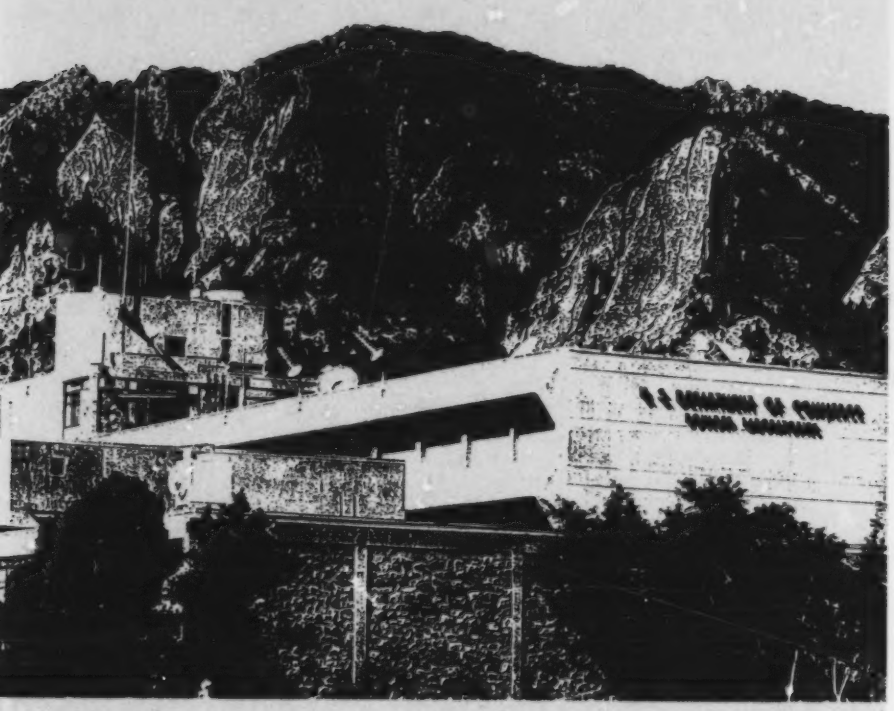
Electromagnetic Technology Division



U.S. Department of Commerce
National Institute of Standards and Technology
Boulder, Colorado 80303-3328

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Mission

The technical scope of the Electromagnetic Technology Division encompasses optical fiber telecommunication systems, other laser systems, superconductors, magnetic materials, and low-temperature electronics. It conducts research leading to the establishment of consistent measurement techniques and standards to serve engineering and commerce. The results of this work are disseminated measurement services, engineering standards and data, other publications, seminars, and collaborative research projects.

The Electromagnetic Technology Division is part of the NIST Center for Electronics and Electrical Engineering (CEEE). Other programs in CEEE provide metrology for electric power engineering, electrical instrumentation, semiconductor electronics, and microwave engineering.

Organization

Electromagnetic Technology Division

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National Institute of Standards and Technology
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Major Facilities

Optical Electronic Metrology

Fast optical pulse measurement
Laser power calibration
Optical fiber measurement
Optical time domain reflectometry
Optical waveguide fabrication and measurement

Cryoelectronic Metrology

Superconducting integrated circuit fabrication:
- high-temperature superconductors
- lead alloy interconnections
- niobium

Superconductor and Magnetic Measurements

AC susceptibility measurement
Critical current versus field measurement
DC magnetic measurement
Eddy current NDE probe characterization
Low-temperature electrical and magnetic measurements
Magnetoresistance measurement
Strain effect measurement

Technical Program

Optical Electronic Metrology

The optical electronic metrology program develops measurement techniques and standards to support optical fiber telecommunications, optical sensors, and other laser systems.

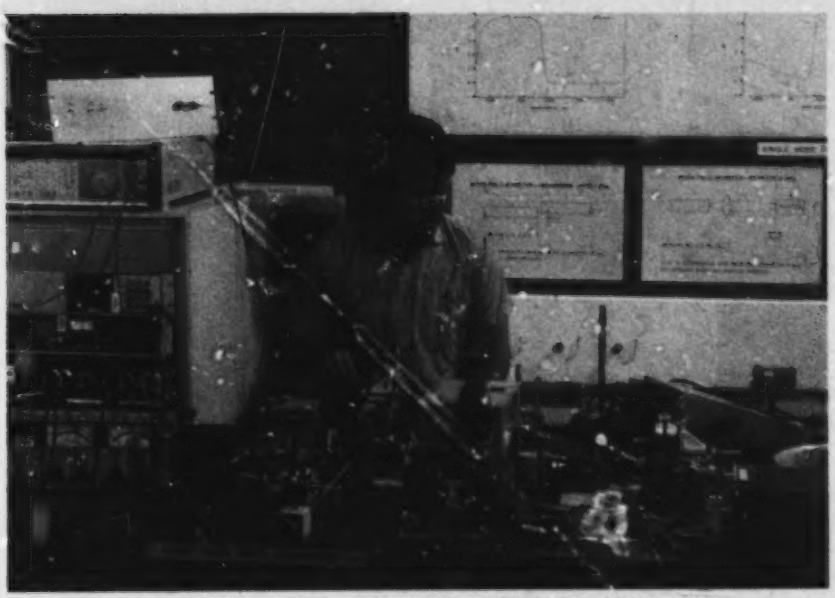
For over a decade we have worked with the Electronics Industry Association (EIA) to establish standard measurement techniques for the characteristics of optical fibers, both multimode and monomode. These techniques were tested in our laboratory and also by "round robin" intercomparisons among the interested parties; then they were refined until they gave consistent results and published as EIA standards. Some of the topics covered by these standards are: attenuation, bandwidth, refractive index profile, core diameter, numerical aperture, mode-field diameter (four different methods reconciled), and cutoff wavelength. Work on standard techniques to measure chromatic dispersion and geometrical factors is in progress.

Optical time domain reflectometers (OTDRs) are used extensively to test systems in the field. We have developed standards for the calibration of OTDRs and are working on the improvement of resolution. A variation of the OTDR principle using incoherent cw radiation can attain micrometer resolution.

The trend in optical fiber telecommunications is toward more sophisticated terminal equipment, that will make available the enormous inherent channel capacity of the monomode fiber

Optical calorimeter power standard (with Igor Vayshenker)

cables that are already installed. Ultimately, all-optical systems including switching, multiplexing, and local distribution are foreseen. Integrated optics will become an increasingly prominent technology needing the support of fully developed measurement methods. We are therefore developing techniques to measure attenuation, refractive index profile, radiation pattern, and coupling of optical waveguides in various substrates, as well as techniques to determine the characteristics of laser diode sources, detectors, and modulators.

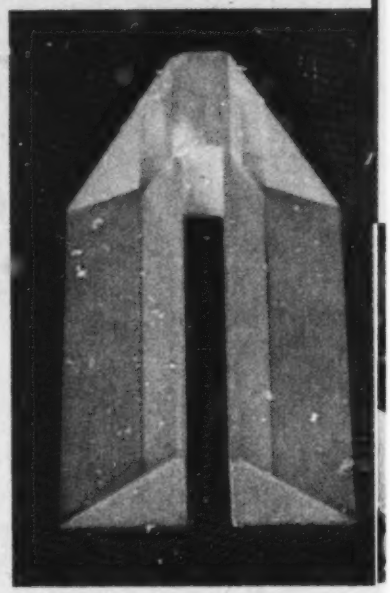


System to measure chromatic dispersion of optical fiber (with Tim Drapela)

We have recently established a calibration service for optical fiber power meters at the wavelengths of interest for telecommunications. It is based on the standards already established for laser power meters. We are developing a calorimeter standard optimized for optical fiber work.

As bit rates increase, it will become necessary to measure the response of all parts of a system to very fast optical pulses. We are developing two systems for this purpose. The first uses a colliding pulse mode-locked (CPM) laser as a source of pulses of short duration (down to 50 fs) in the visible range. The pulses will be down-converted to the wavelength of interest and applied to a variety of sampling and correlation schemes. The other system uses a diode laser source with pulse compression to a few picoseconds to sample the unknown (repetitive) signal by mixing in a nonlinear medium.

Optical sensors that use optical fibers are also coming into increasing prominence. We are working on the measurement and control of the basic fiber characteristics, such as Verdet constant and birefringence, that are important to sensors, and also are developing electric and magnetic sensors using special materials such as bismuth germanate, zinc selenide, and Pockels glass.



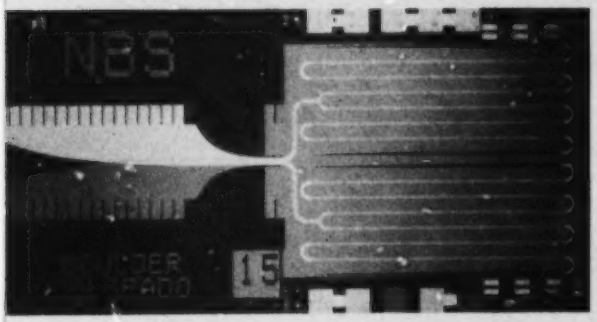
Optical Faraday effect current sensor

We provide calibration service and measurement assurance programs (MAPs) for laser power and energy meters at various levels and wavelengths. The basic standards are isoperibol calorimeters. We are developing a broadband standard to cover the range of wavelength from 0.5 to 15 μm at levels below 1 nW. It is based on a silicon-on-sapphire bolometer. We also develop more specialized standards for measuring from sub-femtojoule levels to multi-megawatt levels for testing various military systems. This effort to provide consistent laser power measurements has had a strong influence on the procurement of military systems and on regulating the safety of all lasers, both military and civilian.

Cryoelectronic Metrology

The cryoelectronic metrology program develops applications of superconductivity (especially the Josephson effect) and other low-temperature phenomena to physical measurements and standards, and assists other organizations (both within and outside NIST) to use the results of this work. This is the nucleus of the NIST Superconductivity Research Center for Electronic Applications, whose major objective is to establish all the fabrication processes required to make practical microcircuits with high-temperature superconductors.

This program started nearly two decades ago with the development of measuring devices that were made from machined parts and used point-contact Josephson junctions. Today the focus of the work is almost exclusively on superconducting microcircuits. We have a fabrication facility capable of making integrated circuits



Voltage standard chip containing a series array of Josephson junctions and microwave feed

of niobium and high-temperature ceramic superconductors. Circuits are defined by photolithography (E-beam lithography is also available) using both lift-off and etching processes. Processes are established for the controlled production of Josephson junctions between niobium films, and research to extend this ability to ceramic superconductor films is in progress. We use computer-aided design and simulation of circuits.

Recent projects have produced a very fast A/D converter, a 30-bit binary counter that counts at rates up to 100 GHz, and SQUID magnetic sensors with noise level close to fundamental quantum

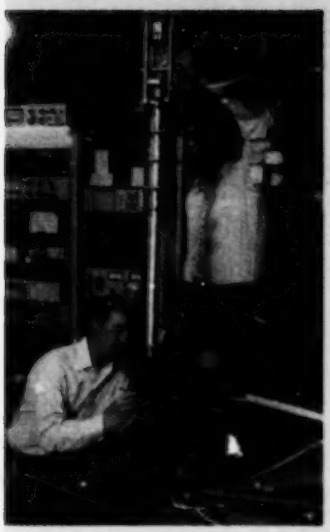
Part of superconducting microcircuit fabrication facility

mechanical limits. The development of the counter is continuing with an effort to create an A/D converter that digitizes a signal applied to an oscillating Josephson junction by counting the oscillations.

The major recent development is a Josephson voltage standard consisting of an array of approximately 19 000 Josephson junctions in a microwave transmission network that drives them uniformly at a frequency near 90 GHz. The array can be latched onto one of a series of quantized voltage steps (at zero bias current) in the range from -10 V to +10 V. Interpolation between steps is done simply by adjusting the frequency. The array is part of a fully automated system that performs a variety of calibration, measurement, and data operations under computer control.

Another major project is a kinetic inductance bolometer. This is a thermal detector based on the variation of inductance of a superconducting circuit with temperature near the transition temperature. It is being developed with the objective of creating a variety of infrared detectors and a microwave power standard.

At a more fundamental level, research to explore the effects of chaos in Josephson junction circuits and to investigate the behavior of very small junctions at very low temperature is in progress. We expect to find new quantum phenomena. A dilution refrigerator is also under construction.



Measurement of the effect of transverse stress on a superconductor (with Jack Ekin and Steve Bray)

Superconductor and Magnetic Measurements

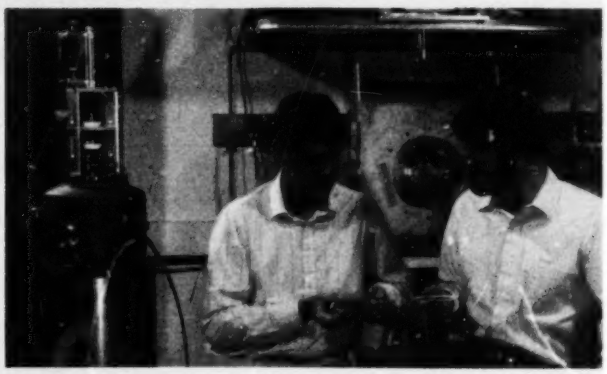
The superconductor and magnetic measurements program performs research to define the engineering characteristics of practical superconductors and develops consistent techniques to measure them. It also performs research on new superconducting materials and develops techniques for a wide range of other ac and dc magnetic measurements, including eddy-current nondestructive evaluation (NDE).

The prime characteristic of a practical superconductor is the variation of its critical current with temperature, magnetic field, elastic strain, and other factors. We have devoted much effort to exploring this variation and determining what experimental conditions must be controlled for consistent measurement. We have developed a standard reference material to test critical-current measurement systems and an ASTM standard method for performing the measurements on small conductors (at less than 600 A). Work to extend this standardization to larger conductors and to investigate the effects of elastic strain on various classes of superconductors is in progress. We have a facility to apply current up to 3000 A in fields up to 12 T. We use the facilities of the MIT National Magnet Laboratory when higher fields are needed. We have tested many prototype conductors under development for major projects, such as the superconducting super collider (SSC) and fusion energy devices.

For over two decades, the measurement of ac and transient loss in superconductors has suffered from gross inconsistencies among different measurement methods. This problem is aggravated by the existence of several ac loss mechanisms that respond differently to experimental conditions. We are performing research aimed at

reconciling these differences. A related problem is that of stability of superconducting systems, which we are also addressing.

Experience with practical low-temperature superconductors has provided a firm base for research on the new high-temperature ceramic superconductors. We have used break and SET junctions (mechanically adjustable junctions) to measure the energy gaps of polycrystalline samples, single crystals, and thin films. These methods have proven particularly valuable in research on superconductivity induced by the proximity effect in thin metal films. We have performed extensive research on the variation of critical-current density with magnetic field, and (in collaboration with researchers at Westinghouse) developed a method for making low-resistance contacts to ceramic superconductors. Properly calibrated measurement of ac susceptibility as a function of temperature has also proven to be a valuable technique for observing the various components of multiphase superconducting materials and for accurate measurement of the isotope effect.



AC susceptometer (with Curt Thompson and Ron Goldfarb)

The magnetics laboratory contains a variety of magnetometers (mostly developed in-house) and an ac susceptometer (also developed in-house) that was recently developed into a commercial product. We are performing research on spin glasses and other new magnetic materials, and on standardizing the measurement of coercivity and other characteristics of materials used for magnetic recording.

We also perform research on the low-temperature transport properties (particularly magnetoresistance) of selected normal metal conductors, such as copper and aluminum-based hyperconductors.

Eddy-current decay is a widely used technique for nondestructive evaluation. Its utility can be greatly enhanced by proper calibration, and we have a program to develop calibration techniques and standards for eddy-current probes. These include standard artifacts on which to test probes and an automated test system.